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(54) **Method for Making Mirrors and Mirrors Made Thereby**

(57) A method of making a mirror for use in solar energy collectors includes:—

(a) placing a plastics sheet carrying thereon a film of highly reflective material over a circular frame which bounds a plenum chamber, and securing it around the frame with the film facing inwardly towards the chamber.

(b) feeding air or gas into the plenum chamber until the sheet is distended outwardly to the desired extent,

(c) placing a curable or hardenable layer of synthetic plastics material onto that surface of the sheet which is opposite to the film,

(d) curing or hardening the layer, and

(e) removing the mirror from the frame.

As an alternative, suction instead of pressure may be employed.

Two such mirrors may be produced by distending a space defined between two superposed reflective sheets.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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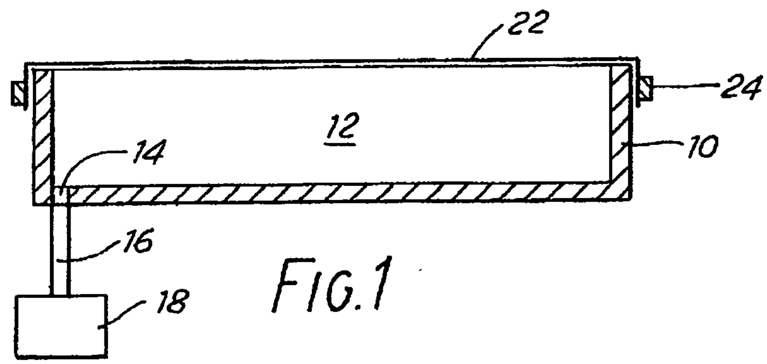


FIG.1

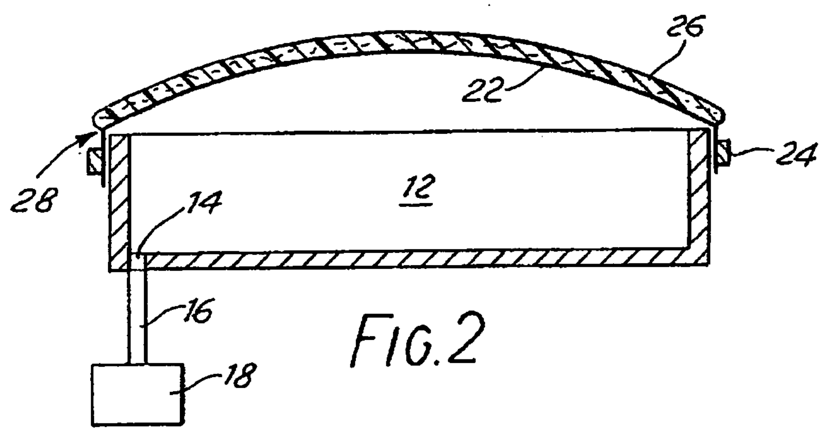


FIG.2

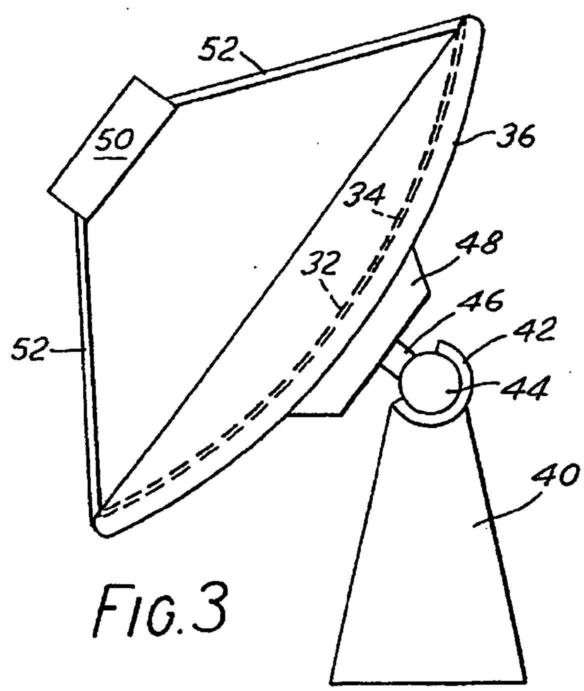


FIG.3

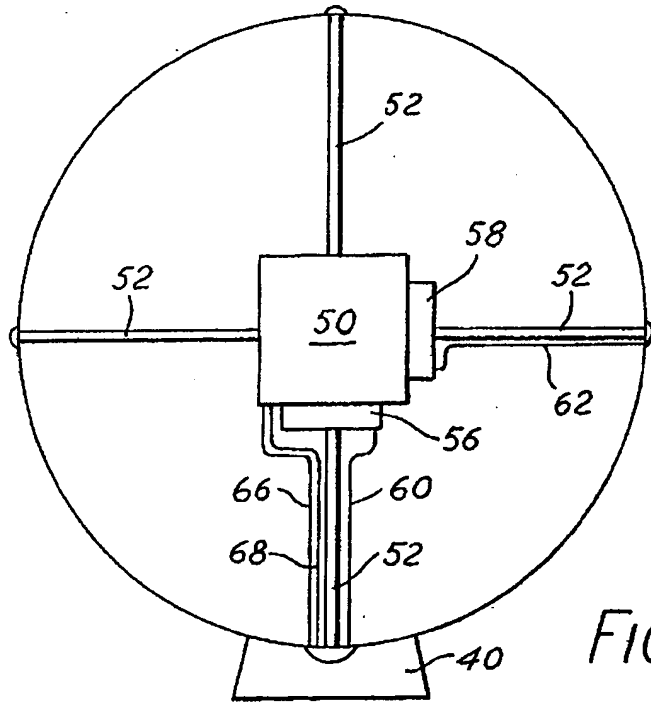


FIG.4

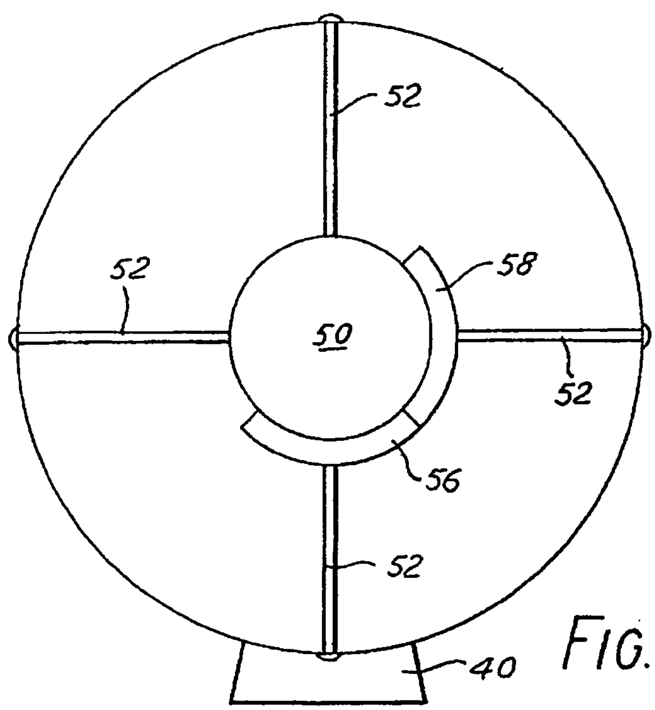


FIG.5

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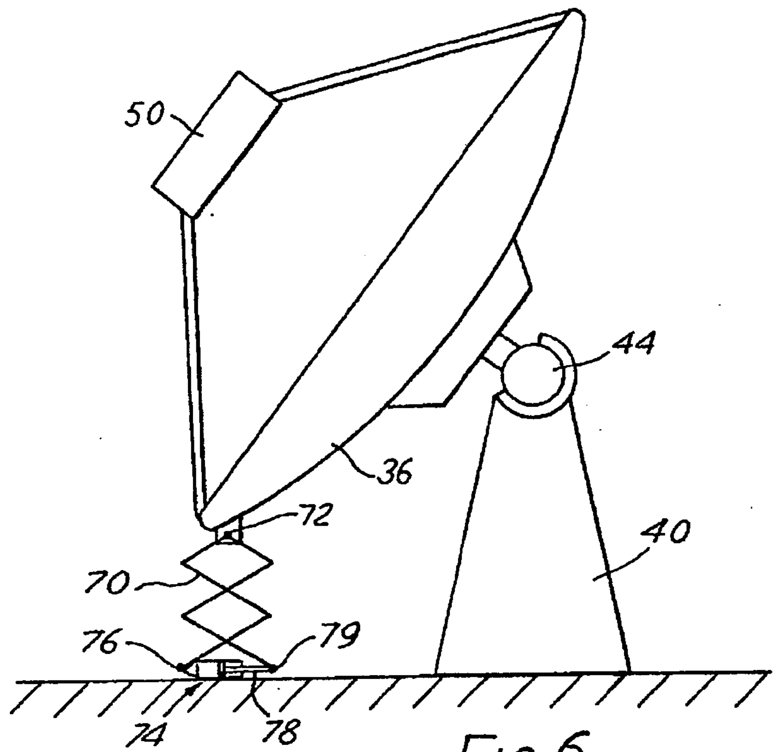


FIG. 6

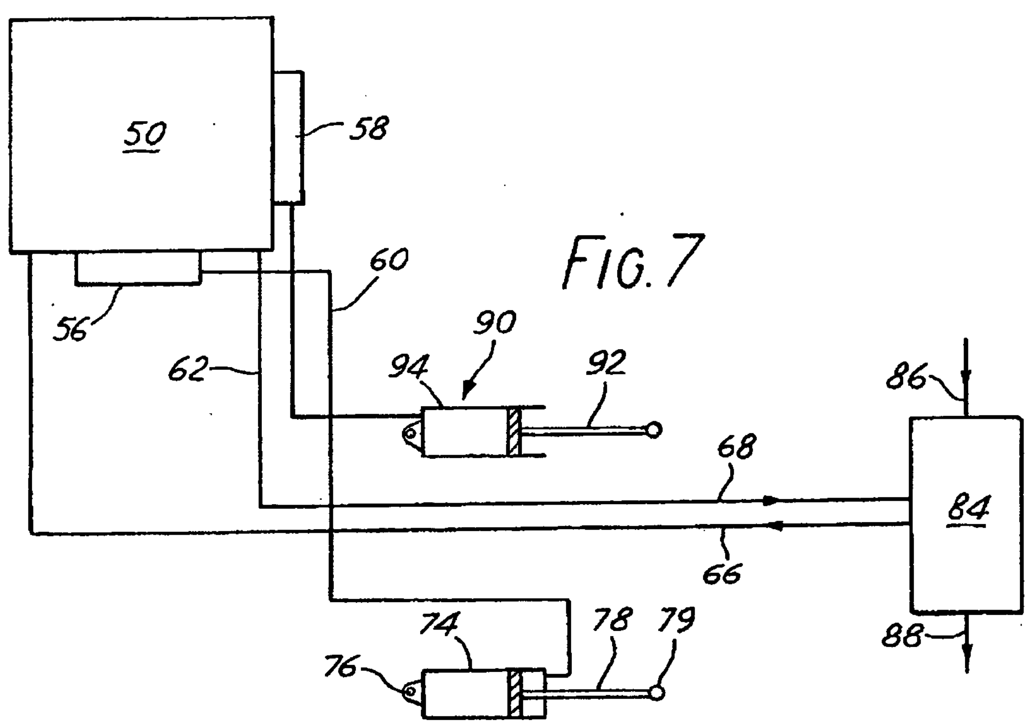


FIG. 7

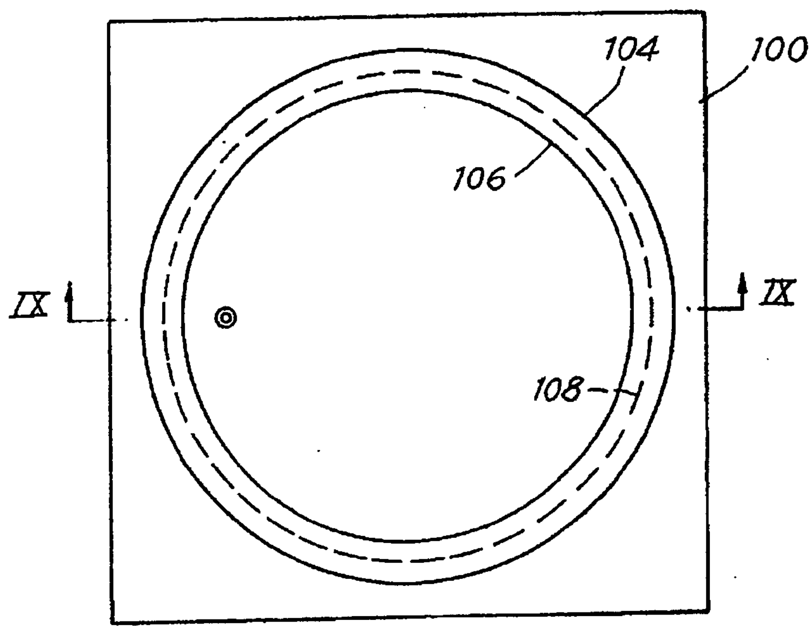
104
100
106
IX
IX
108

FIG.8

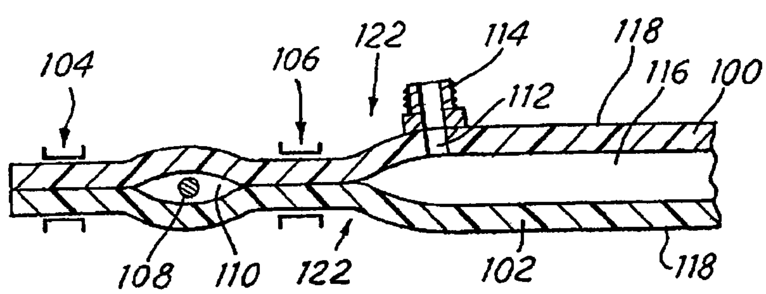
104
106
122
114
118
112
116
100
108
110
122
102
118

FIG.9

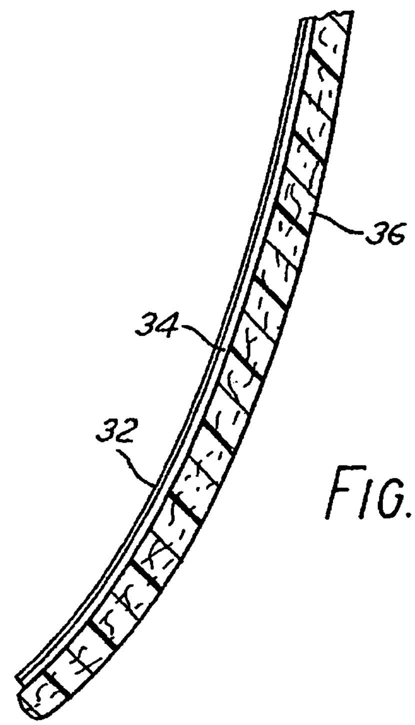


FIG. 10

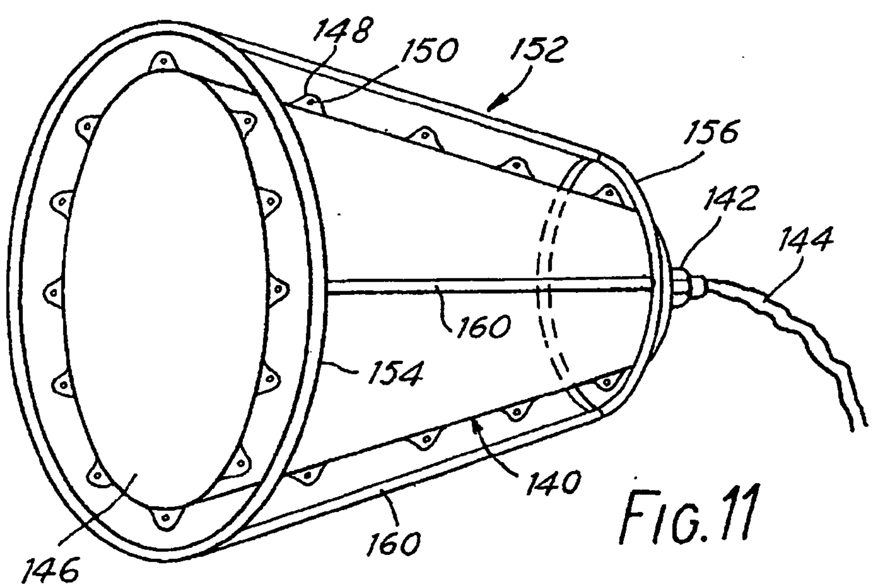


FIG. 11

SPECIFICATION
**Method for Making Mirrors and Mirrors Made Thereby**

This invention relates to the manufacture of mirrors.

Conventionally, mirrors are made by shaping and polishing a metal surface, or by depositing silver on a suitably shaped surface. However, curved (e.g. parabolic) mirrors are expensive to produce, and curved mirrors of relative large diameter, e.g. over one metre in diameter, are particularly expensive.

The high cost of mirrors has been a deterrent to their employment in obtaining useful energy from the sun's rays. With the present high cost of oil, and the likely energy shortage in the future, it would be desirable if a curved mirror could be produced comparatively cheaply.

According to the invention in its broadest aspect, a method of making a mirror includes the steps of holding a plastics sheet in a circular frame, the sheet having thereon a highly reflective film, and then deforming the sheet into a concave shape and holding it in said shape, the film being on the concave surface.

According to the invention, there is provided a method of making a mirror which includes the steps of:—

(a) placing a plastics sheet carrying thereon a film of highly reflective material over a circular frame which bounds a plenum chamber, and securing it around the frame with the film facing inwardly towards the chamber,

(b) feeding air or gas into the plenum chamber until the sheet is distended outwardly to the desired extent,

(c) placing a curable or hardenable layer of synthetic plastics material onto that surface of the sheet which is opposite to the film,

(d) curing or hardening the layer, and

(e) removing the mirror from the frame.

Also according to the invention, a method of making a mirror includes the steps of:—

(a) placing a plastics sheet carrying thereon a film of highly reflective material over a circular frame which bounds a plenum chamber, and securing it around the frame in a gas tight manner with the film facing outwardly away from the chamber,

(b) placing a curable or hardenable layer of synthetic plastics material onto that surface of the sheet which is opposite to the film,

(c) sucking air or gas out of the plenum chamber until the sheet is distended inwardly to a desired extent,

(d) curing or hardening the layer, and

(e) removing the mirror from the frame.

In a preferred form of the invention, the curable or hardenable layer may include glass fibres or chopped glass mat as a reinforcing material.

In an alternative form of the invention, a method of making a pair of mirrors includes placing a pair of plastics sheets one over the other, each of the sheets bearing a film of highly reflective material thereon and the films facing inwardly, welding together the sheets by two circular concentric bar welds, making a hole in one of the sheets within the inner bar weld and attaching a nozzle thereto, placing a circular stiffening member in the space defined between the sheets and the two bar welds, supplying air or gas to the distend the sheets away from one another, placing respective curable or hardenable layers of synthetic plastics material on the surface opposite to the films, curing or hardening the layers, and cutting the assembly around the rim to separate the two mirrors so formed.

The mirror may be provided with a drain hole so that any rain that collects therein can drain away.

In a particular embodiment of the invention which is well suited for the "do it yourself" market, there is provided a plastic bag of conical or frusto-conical shape of which at least the base region of the cone (or the base region of the frustum of a cone) has on its outer surface a highly reflective film; there is also provided a metal or wooden or other rigid three-dimensional framework which has a circular portion of a size such that it can closely surround the base region, the remainder of the framework surrounding the remainder of the bag. The bag is closed except for one orifice to which a nozzle may be attached, and has spaced over its outer surface a plurality of fixing means such as press studs or loops with rings or cringles. There is also provided a corresponding number of press studs or loops on the framework.

In use, the bag is mounted in the frame with the press studs, or by lacing with cord through the loops on the frame and the cringles on the bag. This holds the bag in a generally conical shape with its base region held so as to constitute a generally flat disc. A suction pump is then attached to the nozzle, and the nozzle may be closed, for example by a suitable valve. Some of the air in the bag is evacuated. As a result the base region having the highly reflective film on its outer surface is sucked inwardly and takes up a concave shape, so forming a concave mirror. The framework is then mounted on a suitable support so that the concave mirror can be disposed with its axis pointed substantially at the sun.

The invention will be better understood from the following non-limiting description of an illustrative embodiment thereof, given with reference to the accompanying drawings, in which:—

Figure 1 is a central vertical cross-section through one example of frame usable in the method of the invention, showing a plastics sheet placed thereover;

Figure 2 is a view similar to Figure 1 showing a later stage in the procedure;

Figure 3 is a side elevation view of a mirror in accordance with the invention built into a solar energy collecting device;

Figure 4 is a front view of the device shown in Figure 3;

Figure 5 is a front view similar to Figure 4 but of an alternative design of solar energy collecting device;

Figure 6 is a view similar to Figure 3 and showing a pantograph mechanism for swinging the mirror in a vertical plane;

Figure 7 is a schematic circuit diagram of a simple control circuit for effecting a desired movement of the mirror in response to movement of the sun;

Figure 8 is a plan view of a pair of superposed plastics sheets used in a further embodiment of a method of manufacturing a mirror according to the invention;

Figure 9 is a vertical cross-section, on the plane IX—IX of Figure 8;

Figure 10 is a vertical cross-section on an enlarged scale through part of a mirror in accordance with one example of the invention; and

Figure 11 is a perspective view of a conical framework used in another example of a method according to the invention.

Figure 1 illustrates a frame 10 in the form of a circular dish having upstanding side walls, the interior of the dish constituting a plenum chamber 12 and the dish having a hole 14 therein connected to a pipe 16 which is in turn connected to a pump 18.

The frame is circular about a vertical axis located in the plane of the paper. In operation of one example of a method according to the invention, a plastics sheet carrying thereon a film of highly reflective material is placed over this frame, and is secured thereto in a gas tight manner by an encircling strap 24. The strap 24 may be of flexible metal and may be tightened around the frame 10 by a nut and screw fitting, not shown. In other words, what is commonly known as a "Jubilee" clip of appropriate size may be employed. In fitting the plastics sheet over the frame it is desirable to smooth it out so that it is flat and free from wrinkles before finally tightening the "Jubilee" clip.

Next, air is supplied from the pump 18 into the plenum chamber 12, so distending the plastics sheet 22 into the shape approximately shown in Figure 2. A curable or hardenable synthetic plastics material 26 is then applied to the outer surface of the plastics sheet 22, and optionally one may include glass fibres or glass fibre mat at this stage to provide reinforcement. The purpose of applying the plastics material 26 is to form, after it has hardened, a backing of adequate mechanical strength and rigidity of shape to carry the plastics sheet 22. In a preferred example of the invention, liquid synthetic resin may be applied using a roller in a plurality of layers, said resin including a hardener whose action is initiated by mild application of heat. When several layers have been applied and the glass fibre mat laid therein if desired, the resin is cured by an appropriate application of heat. Thereafter, the sheet 22 is cut around the periphery at the zone indicated by reference numeral 28 in Figure 2 and the resulting mirror is removed. Figure 10 is an enlarged cross-section of part of such a mirror, consisting of a reflective film 32, a synthetic plastics sheet 34 and a supporting substrate 36 of hardened synthetic resin including glass fibres or glass fibre mat. If desired, metal stiffeners may be embedded in the resin 36, or extra layers may be laid on two crossing diameters, so building up ribs which provide extra strength and rigidity to the structure. No further detailed description need be given here, since the techniques of building up rigid curved structures with synthetic resin impregnated with glass fibre are well known in the boat building industry and these techniques may be applied.

In the above description, reference has been made to feeding air or gas under pressure into the chamber 12. According to an alternative embodiment of the invention, not illustrated, a suction pump may be used in replacement of the pump 18 and air may be sucked out of the chamber 12. In this case the sheet is placed with its reflective film on the surface facing away from the chamber and has a curable resin applied to its non-reflective surface in an uncured condition. The sheet carrying the curable resin is then applied to the frame 10 with the reflective film outwardly and air is sucked out of the chamber 12 using the suction pump. When the sheet has been deformed by the external air pressure so that it is concave to the desired extent, heat is applied so curing the resin. The resulting concave mirror may then be removed from the frame.

In yet a further alternative embodiment of the invention, instead of using suction one may arrange things in the manner described in the preceding paragraph and place water on the upper surface of the plastics sheet prior to curing the resin. This stretches it and it takes up a slightly concave form. The resin is then cured by application of heat, the strap 24 is released and the resulting mirror is removed from the frame 10.

According to a preferred feature of the invention, a drain hole is bored in the formed mirror to allow escape of any rain which may collect therein. Such rain water may be collected for drinking or irrigation purposes.

It will generally be desirable to choose a curvature for the mirror such that the focal point is out of reach of a person. This is for obvious safety reasons.

In general, the distension method using air under pressure is preferred.

If it is desired to make a convex mirror, the plastics sheet may be placed with its reflecting film facing inwardly and with the curable resin applied to the concave outer surface. The suction is then applied and held while the resin is cured. The mirror is then removed from the frame.

One use of a mirror in accordance with the invention is as a mirror in a solar energy device. An illustrative solar energy device is schematically depicted in Figure 3. It comprises a base 40 bearing a cup 42 which co-operates with a ball 44 to provide a universally-pivotable ball joint. A

support pillar 46 carries a support 48 which is secured in any convenient way to the glass fibre resin 36 forming part of the mirror. The plastics sheet and film are shown at 34 and 32 in Figure 3.

A spider is constituted by four support rods 52 extending radially inwards from four equally spaced points on the periphery of the mirror. The spider supports a heat exchanger 50. The heat exchanger 50 is disposed substantially at the focal point of the mirror surface 32.

Figure 4 is a front view of the solar energy device shown in Figure 3, with the mirror located so that its axis is substantially horizontal. As seen in Figure 4, the heat exchanger 50 is of generally square shape seen in front elevation and carries two heat sensors 56 and 58 one along its upper side and one along its right hand side as seen from the front. Each of the heat sensors 56 and 58 contains a working fluid whose pressure rises as a result of increasing temperature of the sensor 56 or 58, and a pipe 60 connects the sensor 56 with a device capable of producing mechanical movement in one direction in response to a rise of pressure and in the other direction in response to a fall in pressure. Likewise, a pipe 62 connects the sensor 58 to a similar movement producing device. An entry conduit and an exit conduit 66, 68 carry working fluid to and from the heat exchanger 50.

The purpose of the sensors 56 and 58 is to automatically move the mirror to follow the apparent movement of the sun during the day. In other words, the system is designed to adjust the position of the mirror in both a horizontal and a vertical plane so that its axis at all times points substantially directly at the sun.

The mirror may be moved by an arrangement diagrammatically illustrated in Figure 6, in which a pantograph linkage 70 extends from a pivotal connection 72 on the rim of the mirror backing 36 downwardly to a piston-cylinder device 74. One end of the pantograph linkage is secured to the cylinder at a pivot 76 and the other arm at the lower end of the pantograph linkage is secured by a pivotal connection 78 to the free end of the piston rod 80 of the piston cylinder device 74. The latter has its working space connected to the sensor 56.

A similar pantograph linkage, not shown, may be connected between a point on the mirror periphery at 90° to the point of connection 72, and another piston-cylinder device may be provided in order to allow movement of the mirror around a vertical axis. Figure 7 illustrates the system. Working fluid is fed to the heat exchanger 50 by the conduit 66 and withdrawn therefrom via the conduit 68. A further heat exchanger 84 permits, for example, water entering on line 86 to be heated to steam leaving on line 88. The steam 88 is used as a source of energy for example in a steam turbine, not shown. It will be understood that the energy in the heated working fluid may be extracted and used otherwise than by raising steam. The sensor 56 is connected by the pipe 60 to the piston cylinder device 74, the latter providing the actuating force for operating the pantograph linkage 70 (Figure 6). In a similar way, the sensor 58 is connected by a pipe 62 to a second piston-cylinder device 90 whose piston rod 92 and whose cylinder 94 are respectively connected to a second pantograph linkage connected to the mirror as described above. The piston cylinder device 74 effects angular motion of the mirror about a horizontal axis passing through the centre of the ball 44 and the piston-cylinder device 90 effects angular motion of the mirror about a vertical axis passing through the centre of the ball 44.

With respect to the adjustment about a horizontal axis, it can be seen that as the sun rises, and assuming the mirror does not move, the sun's rays become focused at a point lower with respect to the centre of the heat exchanger 50 than earlier in the day. Therefore, the sensor 56 is heated and the pressure of the sensing fluid therein increases. Consequently this increased pressure is transmitted by the line 70 to the piston-cylinder device 74, and its piston rod is consequently forced inwardly, so pulling the pivot points 76 and 78 closer together and therefore increasing the height of the pantograph linkage 70, thus driving the mirror to follow the rising sun. As a consequence, the mirror swings upwardly about the horizontal axis through the centre of the ball 44 and the sensor 50 is positioned in substantial registry with the focal point of the sun's rays. The sensor 56 continues to operate in this way as the sun rises, continuously pivoting the mirror upwardly.

Adjustment of position of the mirror about a vertical axis through the centre of the ball 44 is carried out in a similar way, using a piston-cylinder device 90 linked to the lateral sensor 58, the device 90 being connected to a similar pantograph linkage attached to a point at half height of the mirror on the mirror periphery.

An alternative configuration of heat exchanger 50 and sensors 56 and 58 is shown in Figure 5, the principal distinction being that the heat exchanger 50 is of circular shape seen in front elevation and the sensors 56 and 58 are each arcuate, covering 90° of the periphery. It will be appreciated that it is not essential that the heat exchanger 50 be located exactly at the focal point. Good results can be achieved with the heat exchanger 50 being located either further from or nearer to the mirror than the focal point, and indeed in hot countries this will be preferable in order to prevent the temperature of the heat exchanger 50 being raised to a level at which it would be essential to make the heat exchanger 50 of expensive high temperature materials. It will be understood that the principle of control will still be applicable even though the heat exchanger 50 is not located in the focal plane.

The heat exchanger 50 may be any conventional design of heat exchanger. As a preferred feature, its surface which faces towards the sun may be ribbed or finned in order to

provide an increased surface area. The working fluid passed therethrough may be water. The working fluid pipes 66, 68 and the sensor conduits 60, 62 may be carried along the rods 52, along the back of the mirror support 36, and then via lengths of flexible hose, around the universal joint and to the base 40. It will be realised that it is important not to significantly restrain the pivoting movement of the mirror.

The synthetic plastics sheet bearing a highly reflective film, used as the mirror surface, may be a material of this kind developed by National Aeronautics and Space Agency of United States of America. This material is now commercially available.

Each piston-cylinder device 74, 90 may be provided with a pressure relief valve as a safety measure in case movement of the mirror is stopped by an obstruction and hence pressure builds up in one of the piston cylinder devices. The pressure relief valve is not shown in the drawings. The working surface of the heat exchanger 50 will preferably be painted or otherwise coated to produce a matt black surface.

An alternative method of manufacture of a mirror according to the invention is illustrated in Figures 8 and 9. In this method of making a mirror, two sheets of plastics material 100 and 102 each having a highly reflective film on one surface thereof are placed face to face with the reflecting films inwards. Then a pair of circular bar welds 104, 106 are made, so fusing together the two sheets at the indicated locations, and a wire cable 108 is placed in the space 110 between these welds. Then a hole 112 is punched or formed in the layer 100 and a nozzle 114 is welded to said layer. A source of air or gas under pressure such as a pump is connected to the nozzle 114 and the space 116 within the inner bar weld is inflated. This causes the two plastics sheets to distend outwardly. The nozzle is then closed off and layers of synthetic resin incorporating glass fibre mat are build up on the outer surfaces 118 of the two sheets. The resin is cured to provide a firm support for the mirror and a circular cut is made at the location indicated by 122. In this way, two mirrors in accordance with the invention can be formed in one operation.

A further embodiment of a method in accordance with the invention is illustrated in Figure 11. In this embodiment, instead of employing a container such as the container 10 to define a plenum chamber, the mirror surface is formed by the base of a conical or frusto-conical bag made of plastics material, at least the base region bearing a highly reflective film. Air is extracted from the interior of such a bag via a nozzle, and the bag is held substantially in conical or frusto-conical shape by an external framework which may be made of metal, for example. Referring now to Figure 11, there is shown a bag made of plastics sheet material at 140 having an orifice therein provided with a nozzle 142 to which is attached a pipe 144 leading to a suction pump, not shown. As will be seen, the bag 140 is of frusto-conical shape having a base region 146 which is initially flat. The bag 140 is provided with a plurality of tabs each containing a cringle, one tab being shown by 148 and one cringle by 150. The purpose of these is to enable the bag 140 to be held in substantially frusto-conical shape by suitable cord or rope lacings, not shown. A frusto-conical framework 152 surrounds the bag 140, and consists as shown of two circular members 154 and 156 joined by straight rods 160. It will be understood that the drawing is diagrammatic. In fact, it may be desirable to include more than four rods 160 and more than two circular members, in order to hold the bag 140 substantially in a frusto-conical shape. The cord lacings are led from the cringles to the adjacent framework member, and pulled tight to ensure a reasonable degree of stability of shape of the plastics bag 140.

When this has been done, air is evacuated from the interior of the bag 140, so causing the base region 146 to take up an inwardly bowed formation. In other words, it takes up a concave shape with the concave surface being that bearing the highly reflective film. A valve in the pipe 144 is closed when the film has taken up the desired degree of concavity. One then has a curved reflecting mirror which can be made without any great skill by a person interested in "Do it yourself" activities, and moreover the parts necessary for making the mirror can be easily and cheaply manufactured and readily packaged in a relatively small space. Consequently it is believed that such a mirror will have a wide appeal to householders who are interested in themselves deriving some benefit from solar energy. Having erected the mirror, all that is necessary is for a heat exchanger to be mounted appropriately in relation thereto. A suitable heat exchanger may be mounted at the centre of a "spider" constituted by an array of radial rods, and these rods may be provided with end fittings which will clip onto the circular member 154. In this way, a heat exchanger can be securely located accurately in relation to the mirror surface 146 at or near its focal point.

The production of a mirror in the manner particularly disclosed and illustrated herein gives a number of advantages. Firstly, mirrors of quite large size can be readily produced on site, so avoiding awkward transport problems. The method of production is simple and uses established technology; it is sufficiently easy to be carried out by a competent "do it yourself" operator. Compared to highly polished mirrors prepared by conventional methods, the procedure is extremely cheap, for example a curved mirror about two metres in diameter could be produced for a total cost of only a few hundred pounds, compared to a cost of several thousand pounds if it was produced by a conventional method. When applied in a solar energy device, a mirror according to the invention as particularly described herein will produce an immediate return of investment and gives an opportunity for

a reasonably competent householder to himself build and use a solar energy device. This is expected to be of increasing value as the cost of coal and petroleum-based fuels continues to rise. The curvature of mirrors produced by the distention method disclosed is of satisfactory accuracy.

## Claims

1. A method of making a mirror which includes the steps of:—

(a) placing a plastics sheet carrying thereon a film of highly reflective material over a circular frame which bounds a plenum chamber, and securing it around the frame with the film facing inwardly towards the chamber,

(b) feeding air or gas into the plenum chamber until the sheet is distended outwardly to the desired extent,

(c) placing a curable or hardenable layer of synthetic plastics material onto that surface of the sheet which is opposite to the film,

(d) curing or hardening the layer, and

(e) removing the mirror from the frame.

2. A method of making a mirror includes the steps of:—

(a) placing a plastics sheet carrying thereon a film of highly reflective material over a circular frame which bounds a plenum chamber, and securing it around the frame in a gas tight manner with the film facing outwardly away from the chamber,

(b) placing a curable or hardenable layer of synthetic plastics material onto that surface of the sheet which is opposite to the film,

(c) sucking air or gas out of the plenum chamber until the sheet is distended inwardly to a desired extent,

(d) curing or hardening the layer, and

(e) removing the mirror from the frame.

3. A method according to claim 1 or 2 in which the curable or hardenable layer may include glass fibres or chopped glass mat as a reinforcing material.

4. A method of making a pair of mirrors which includes placing a pair of plastics sheets one over the other, each of the sheets bearing a film of highly reflective material thereon and the films facing inwardly, welding together the sheets by two circular concentric bar welds, making a hole in one of the sheets within the inner bar weld and attaching a nozzle thereto, placing a circular stiffening member in the space defined between the sheets and the two bar welds, supplying air or gas to distend the sheets away from one another, placing respective curable or hardenable layers of synthetic plastics material on the surface opposite to the films, curing or hardening the layers, and cutting the assembly around the rim to separate the two mirrors so formed.

5. A method according to any one of claims 1—4 which includes providing a drain hole in the mirror.

6. A method according to any one of claims 1—5 which includes providing one or more stiffening ribs within the curable or hardenable resin layer.

7. A mirror comprising a support layer constituted by a cured or hardened resin layer, and a sheet of plastics material thereon said sheet bearing a reflective film on one surface thereof.

8. A mirror according to claim 7 in which the resin layer includes reinforcing fibres.

9. A mirror according to claim 7 or 8 in which the resin layer includes glass fibres or glass fibre mat as reinforcement.

10. A mirror according to claim 7, 8 or 9 in which the support layer includes at least one diametral reinforcing rib.

11. A mirror according to claim 10 in which the reinforcing rib is of steel.

12. A method of making a mirror which includes the steps of holding a plastics sheet in a circular frame, the sheet having thereon a highly reflective film, and then deforming the sheet into a concave shape and holding it in said shape, the film being on the concave surface.

13. A method according to claim 12 in which the sheet is in the form of a bag of conical or frusto-conical shape, in which the film is on at least the outer surface of the base region of the bag, the bag is held in a conical or frusto-conical frame, and the interior of the bag has air evacuated therefrom in order to deform the base region into a concave shape.

14. A method according to claim 13 in which the bag has tabs thereon by which it can be connected to the frame.

15. A method according to claim 14 in which the tabs carry cringles and the bag is tied to the frame by tape, cord, string, rope or an equivalent thereof.

16. A method according to claim 13 in which the bag is connected to the frame by press-studs or other mechanical fasteners.

17. A method according to any of claims 13—16 in which a spider carrying a heat exchanger is clipped to the frame so that the heat exchanger is located substantially at the focal point of the mirror.

18. A method of making a mirror substantially as herein particularly described with reference to and as illustrated in the accompanying drawings.

19. A mirror substantially as herein particularly described with reference to and as illustrated in the accompanying drawings.

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